Using a Steady State Model of an Aluminum Reduction Cell to Investigate the Impact of Design Changes

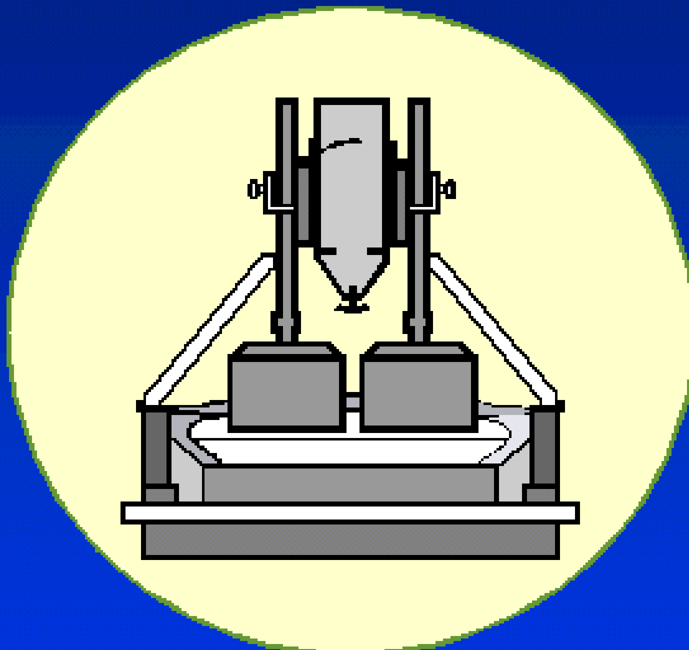
Marc Dupuis — GéniSim Inc.

Imad Tabsh — CompuSIM Inc.

Steady State Model
Program Overview

Idealized system consists of the :

- Liquid Zone (Bath and Metal)
- Solidified Ledge



Solution strategy consists of :

Internal Heat - Heat Loss = 0

Standard Newton Raphson algorithm

Process Model : Heat Balance Equation

Internal Heat

- Evaluated by computing the voltage break down:
  - Bath Composition
  - Bath Resistivity
  - Bath Liquidus
  - Current Efficiency
  - Bath Voltage
  - Electrolysis Voltage
  - Equivalent Voltage to Make Metal

Global Heat Loss

- Four surfaces are defined for losing heat:
  - Anode Panel
  - Cathode Panel
  - Freeze Adjacent to Bath Layer
  - Freeze Adjacent to Metal Layer

GENISIM

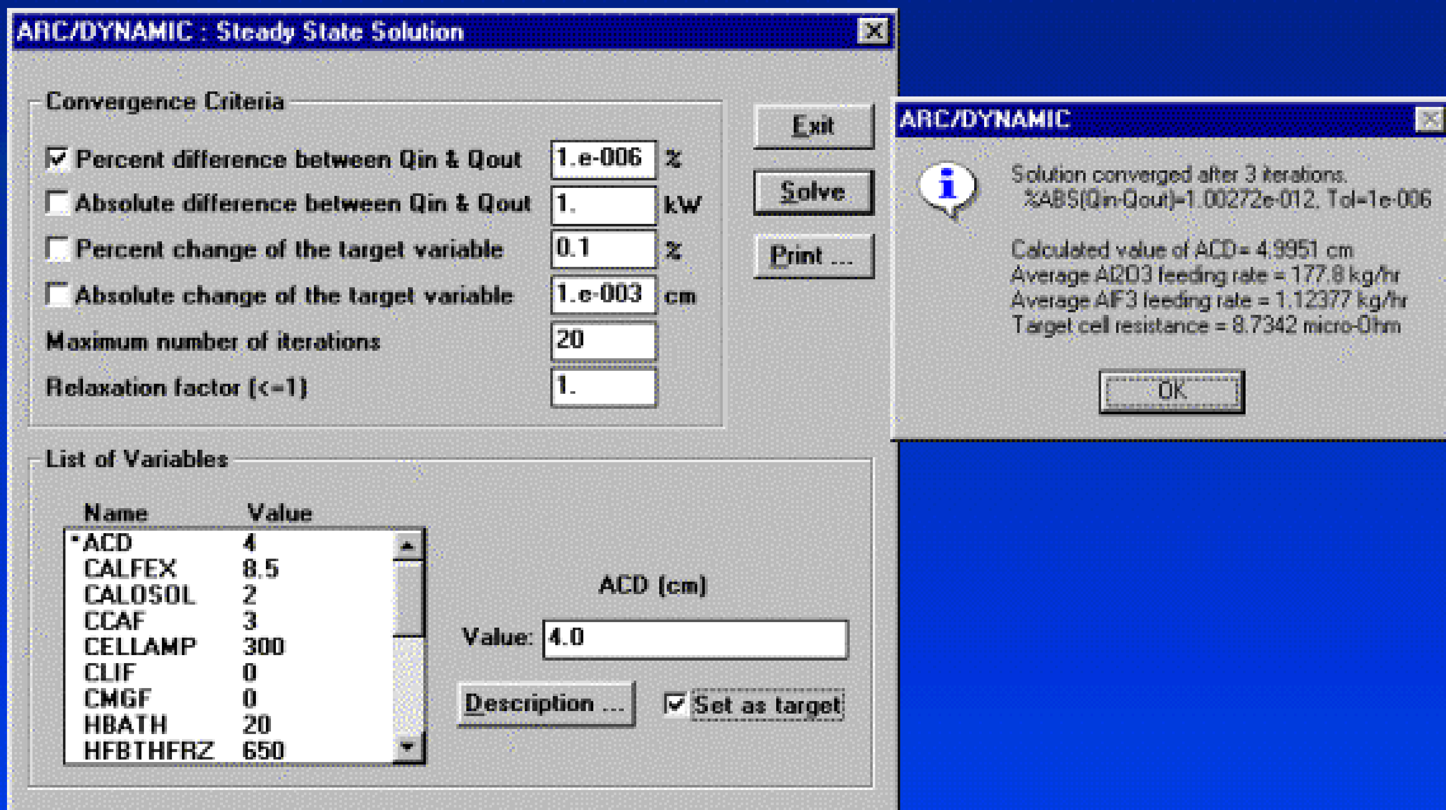
Choice of Root Search "Variable"

- Any of the following parameters can be selected as the "variable" of the root search algorithm :

- Amperage of the cell	- Length of the anodes
- Anode to cathode distance	- Width of the anodes
- Concentration of excess AlF_3	- Heat loss of anode panel
- Concentration of dissolved Al_2O_3	- Anode voltage drop
- Concentration of CaF_2	- Length of the cell cavity
- Concentration of LiF	- Width of the cell cavity
- Concentration of MgF_2	- Heat loss of the cathode panel
- Height of bath	- Cathode voltage drop
- Height of metal	- Cell operating temperature

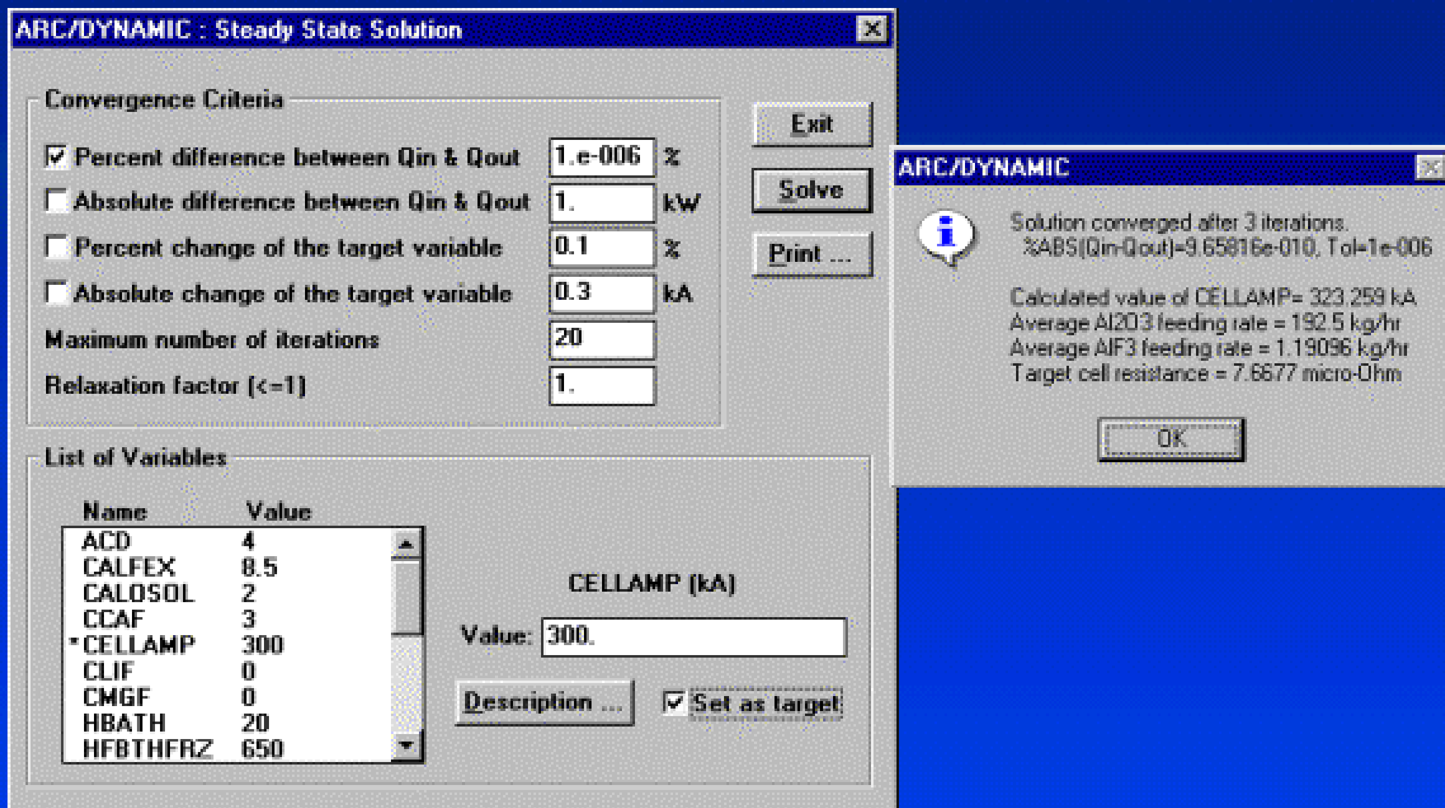
GENISIM

Example of Application

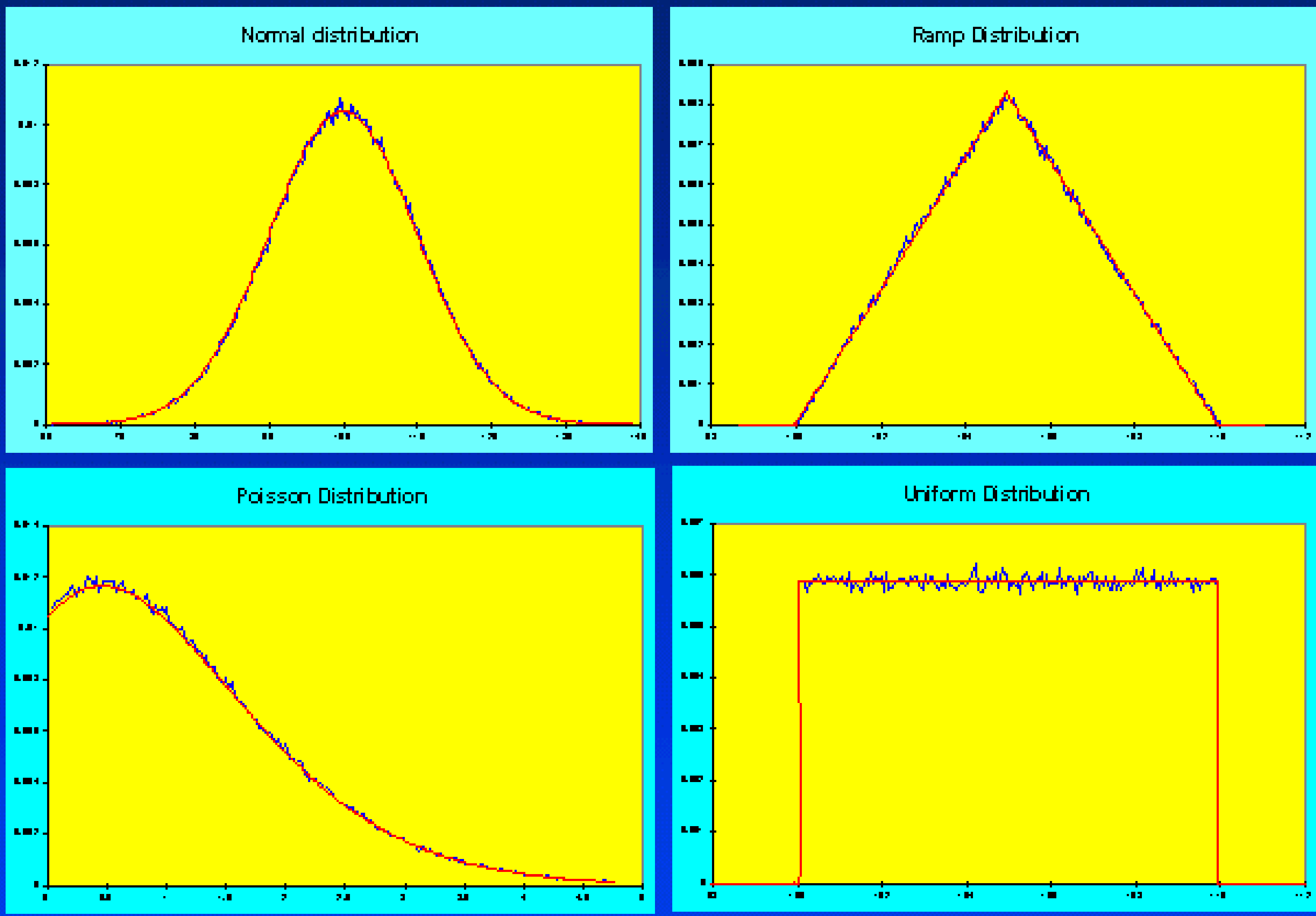


GENISIM

Example of Application

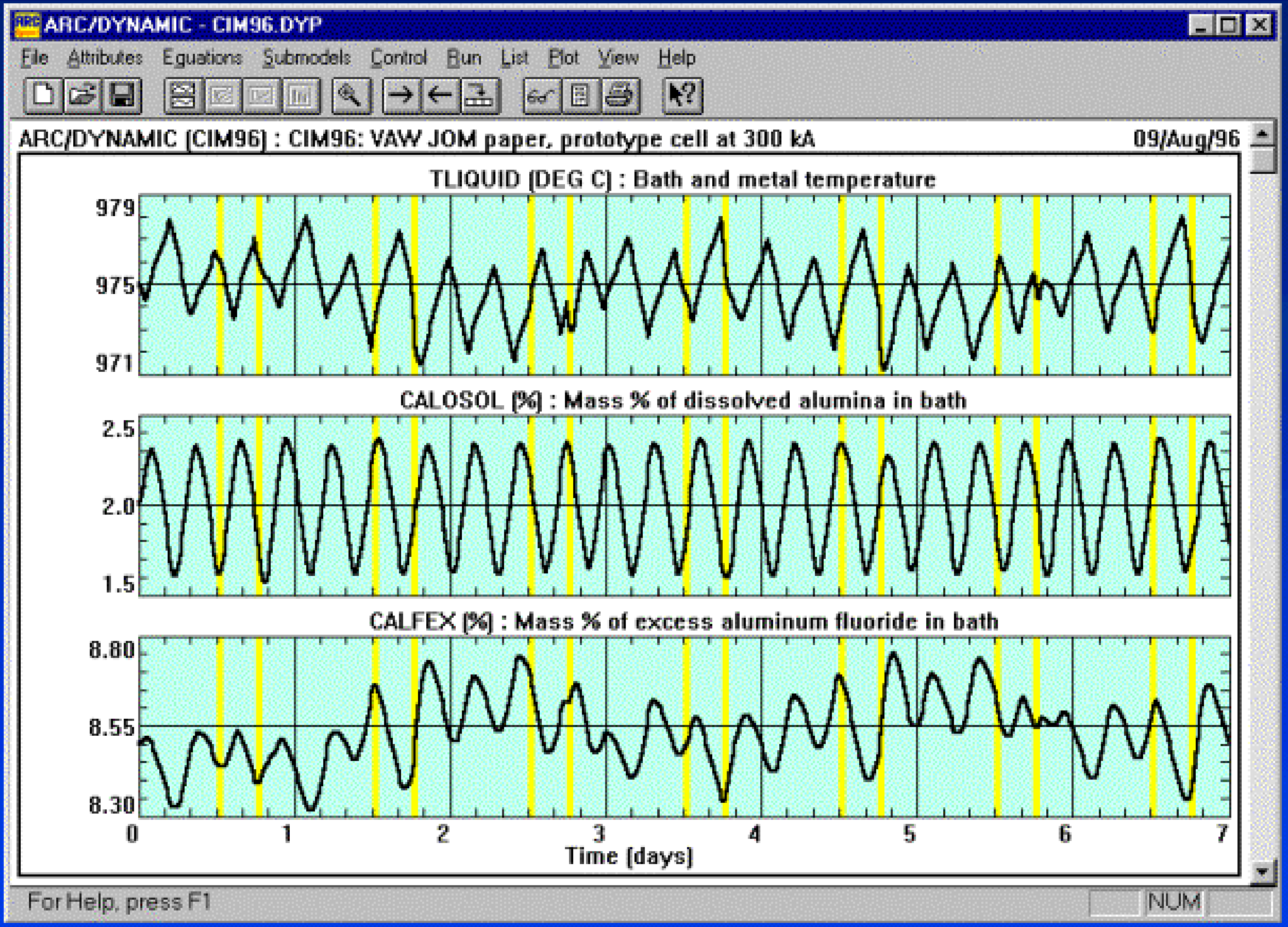


Monte Carlo Input Parameter Distributions



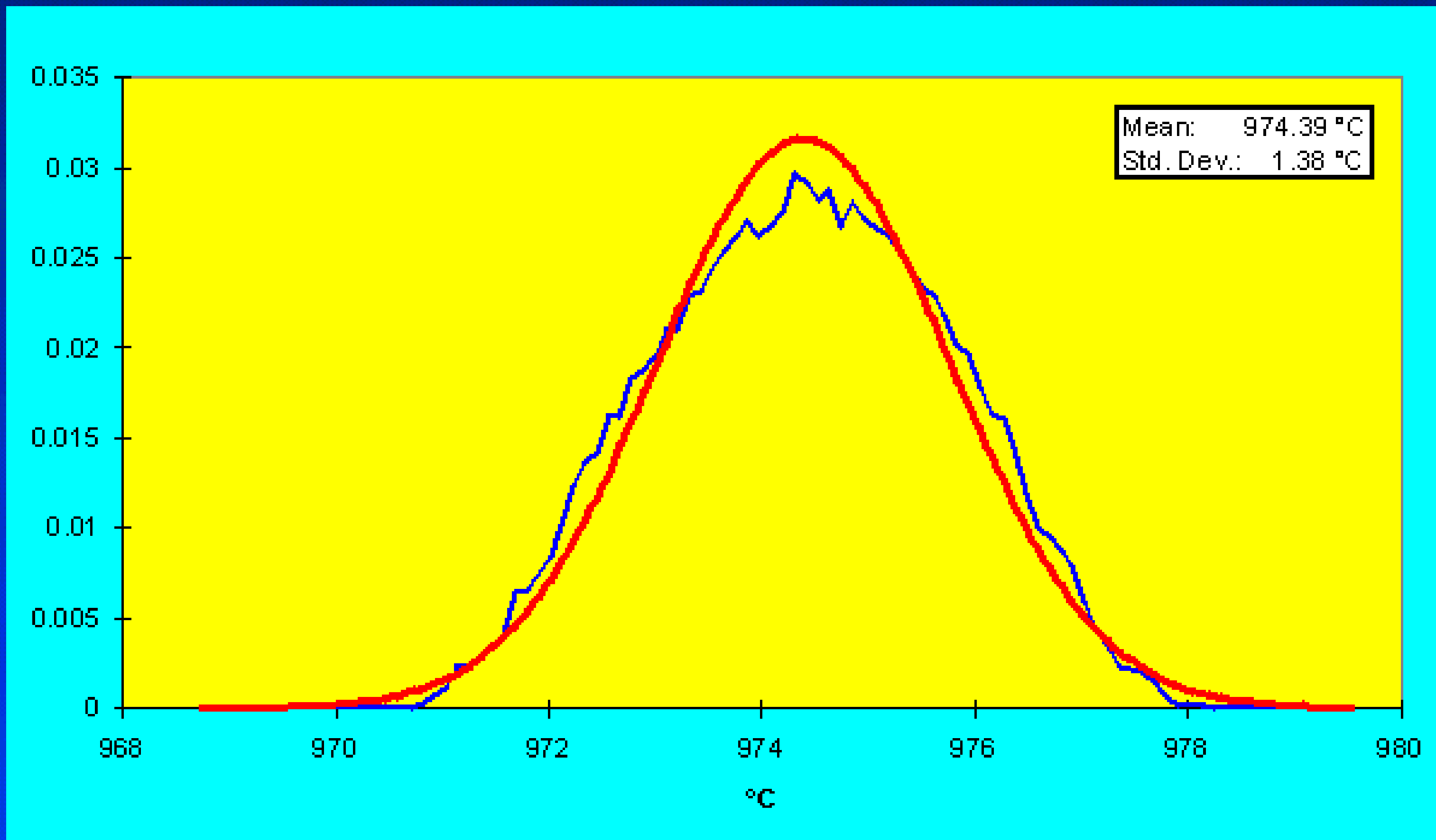
GENISIM

Analysis of Dynamic Response



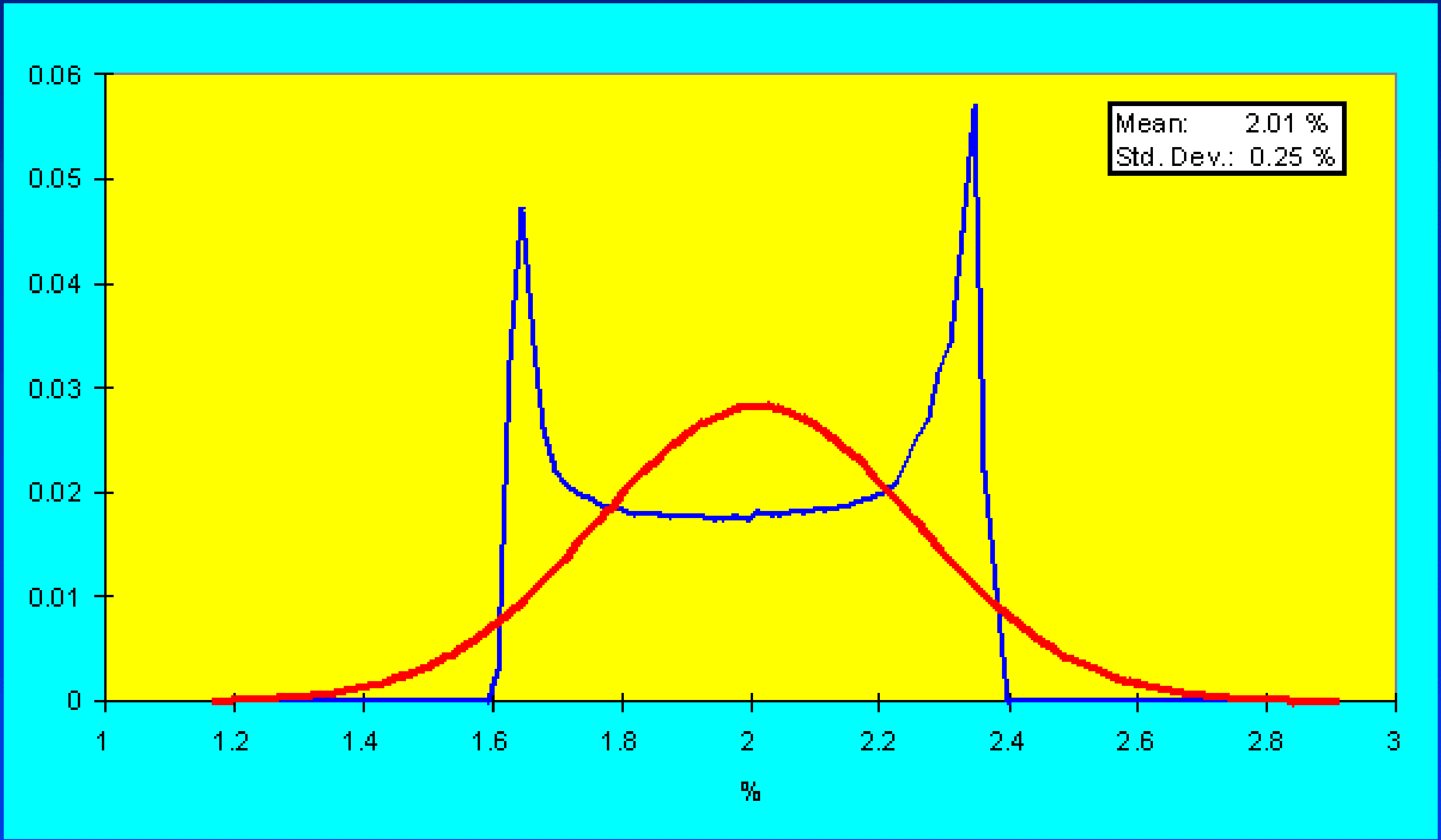
GENISIM

Dynamic Temperature Distribution



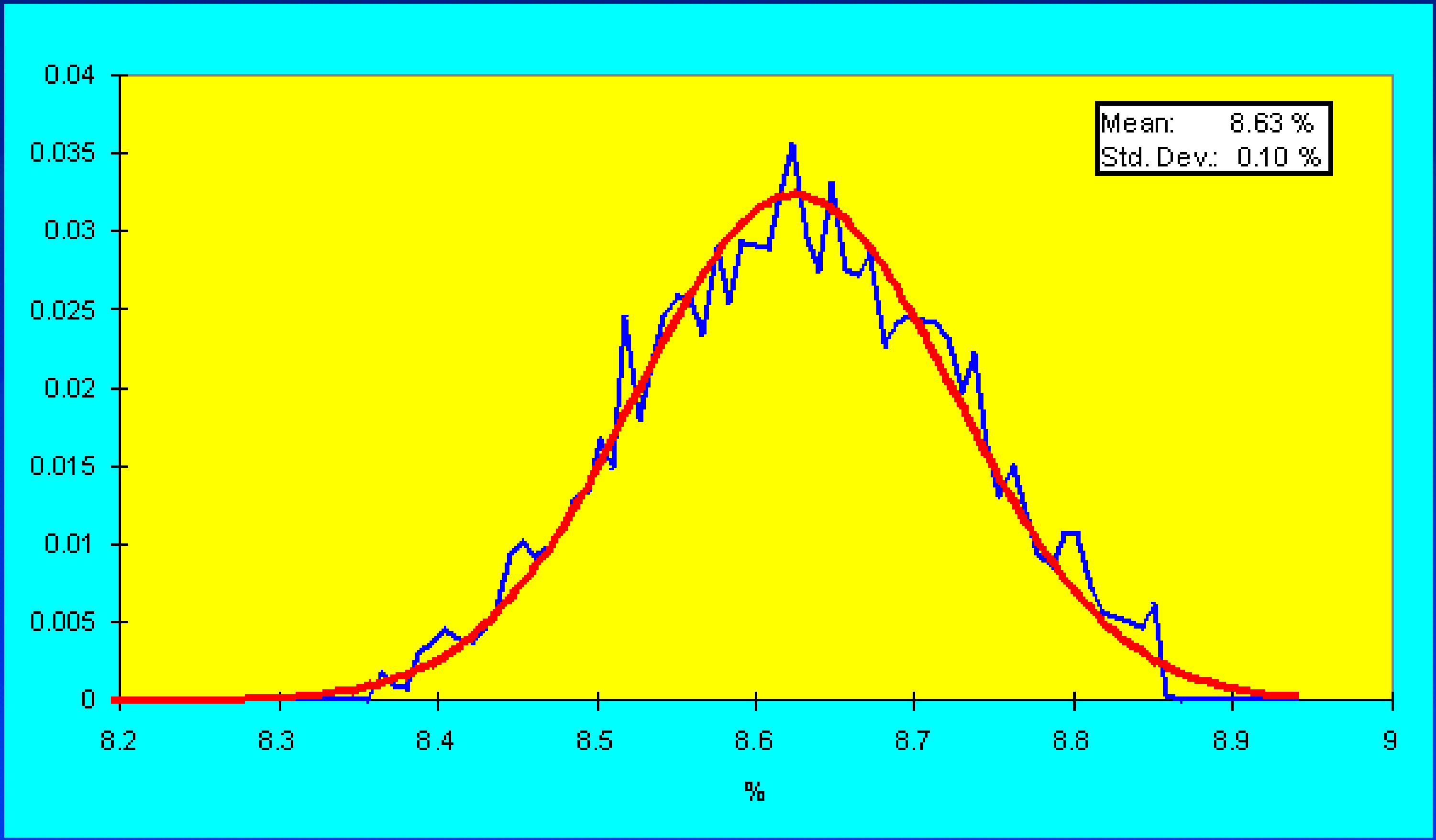
GENISIM

Dynamic Dissolved Al_2O_3 Distribution



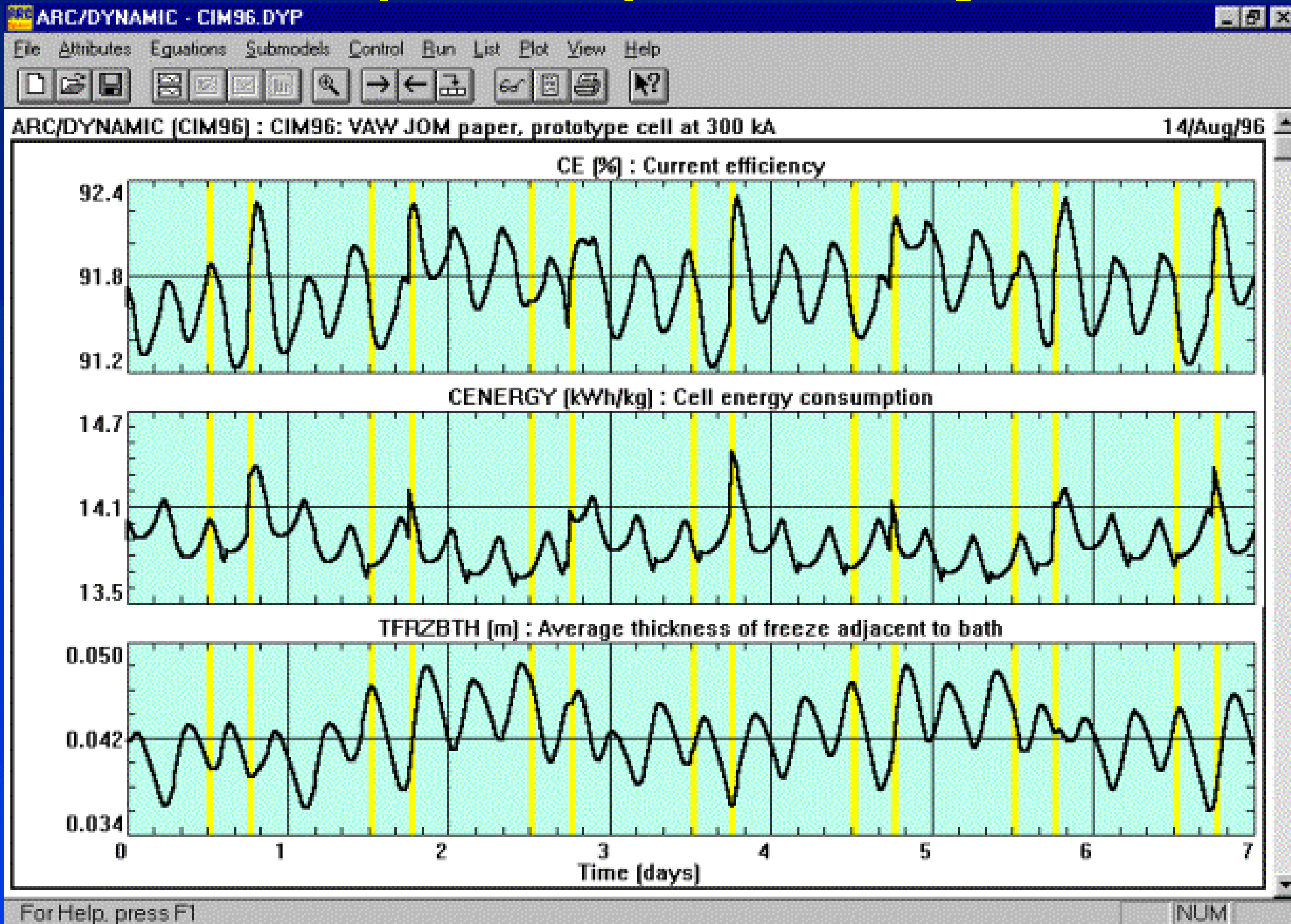
GENISIM

Dynamic Excess AlF_3 Distribution



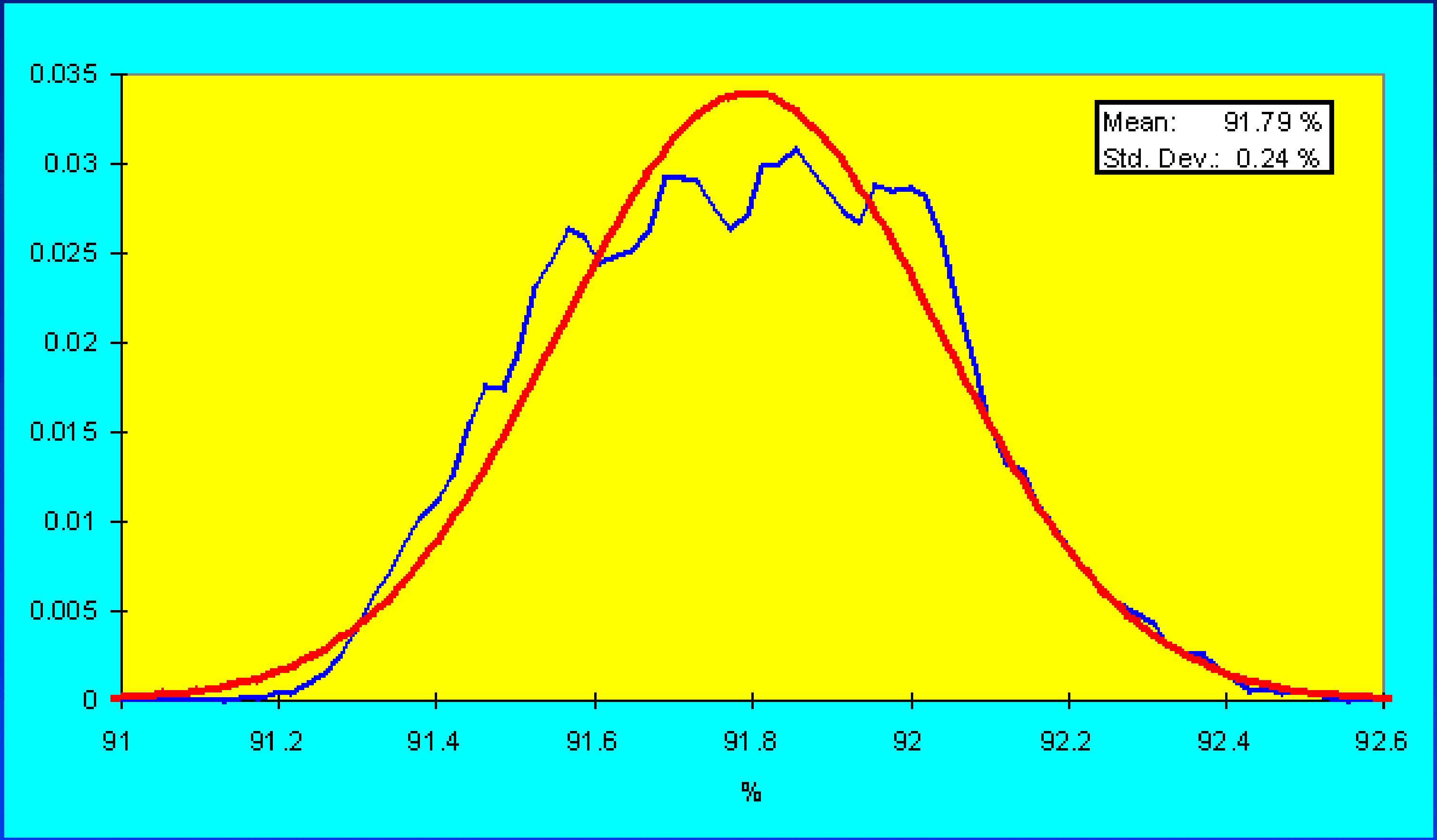
GENISIM

Analysis of Dynamic Response



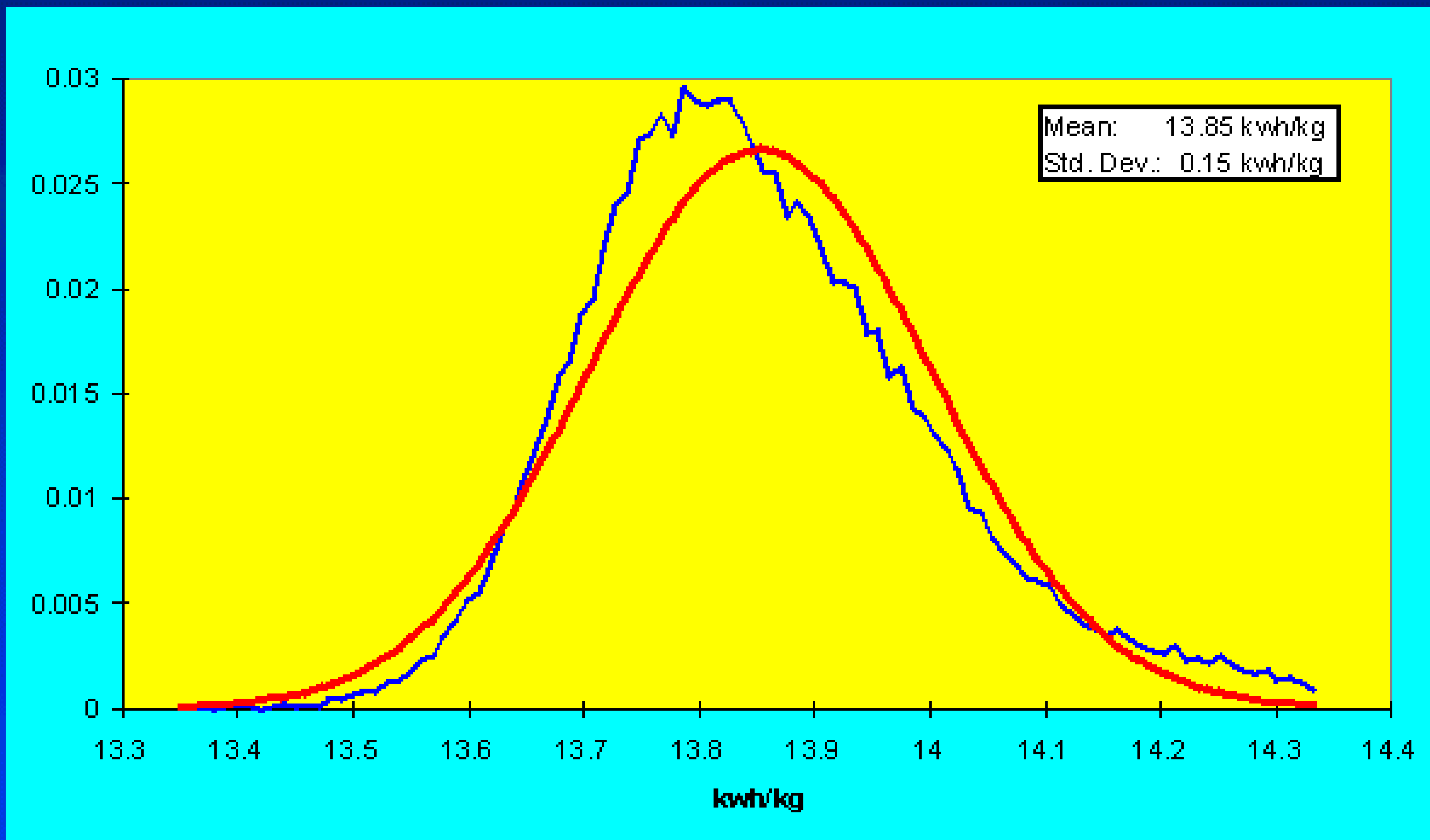
GENISIM

Dynamic Current Efficiency Distribution

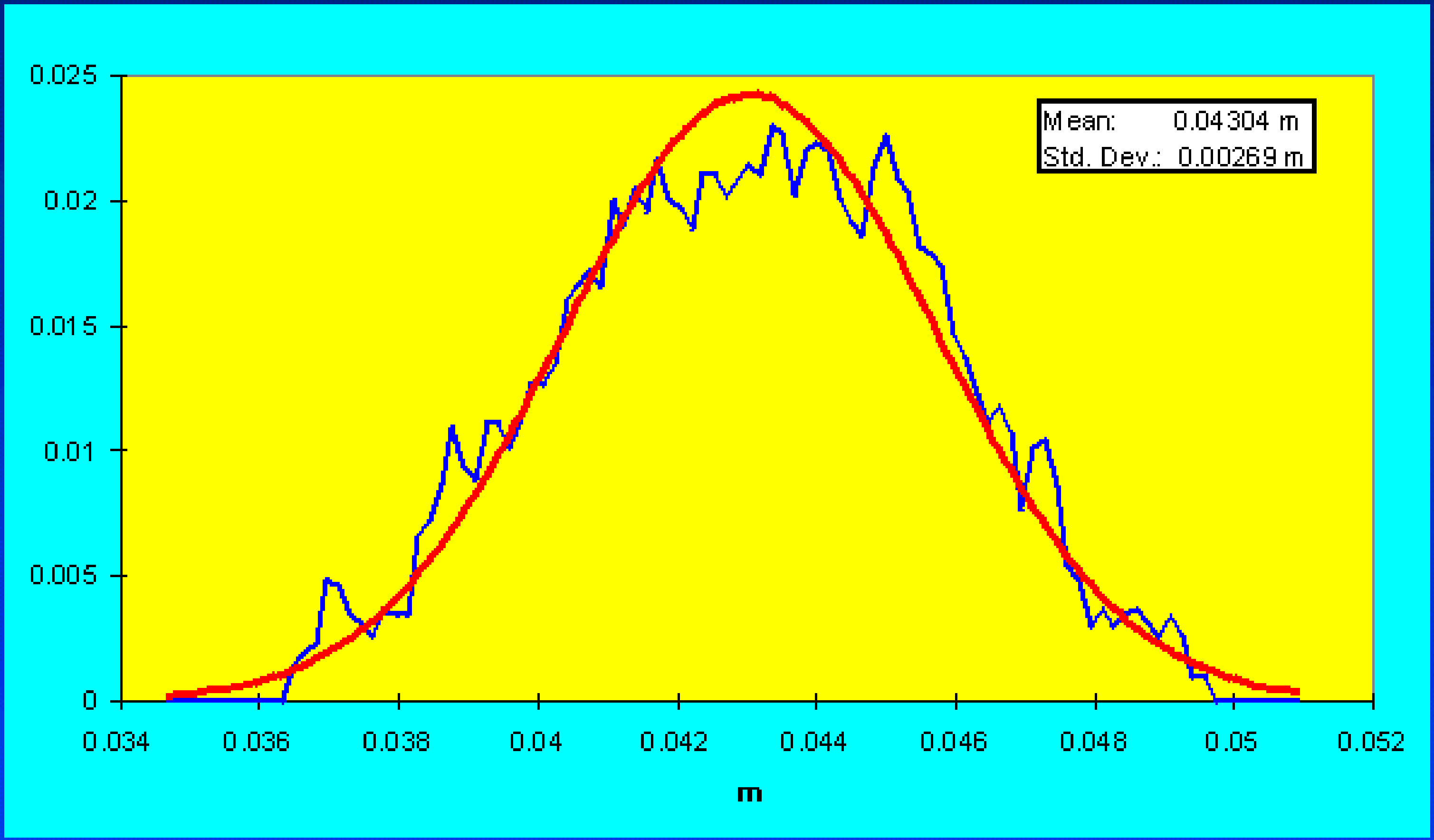


GENISIM

Dynamic Energy Consumption Distribution

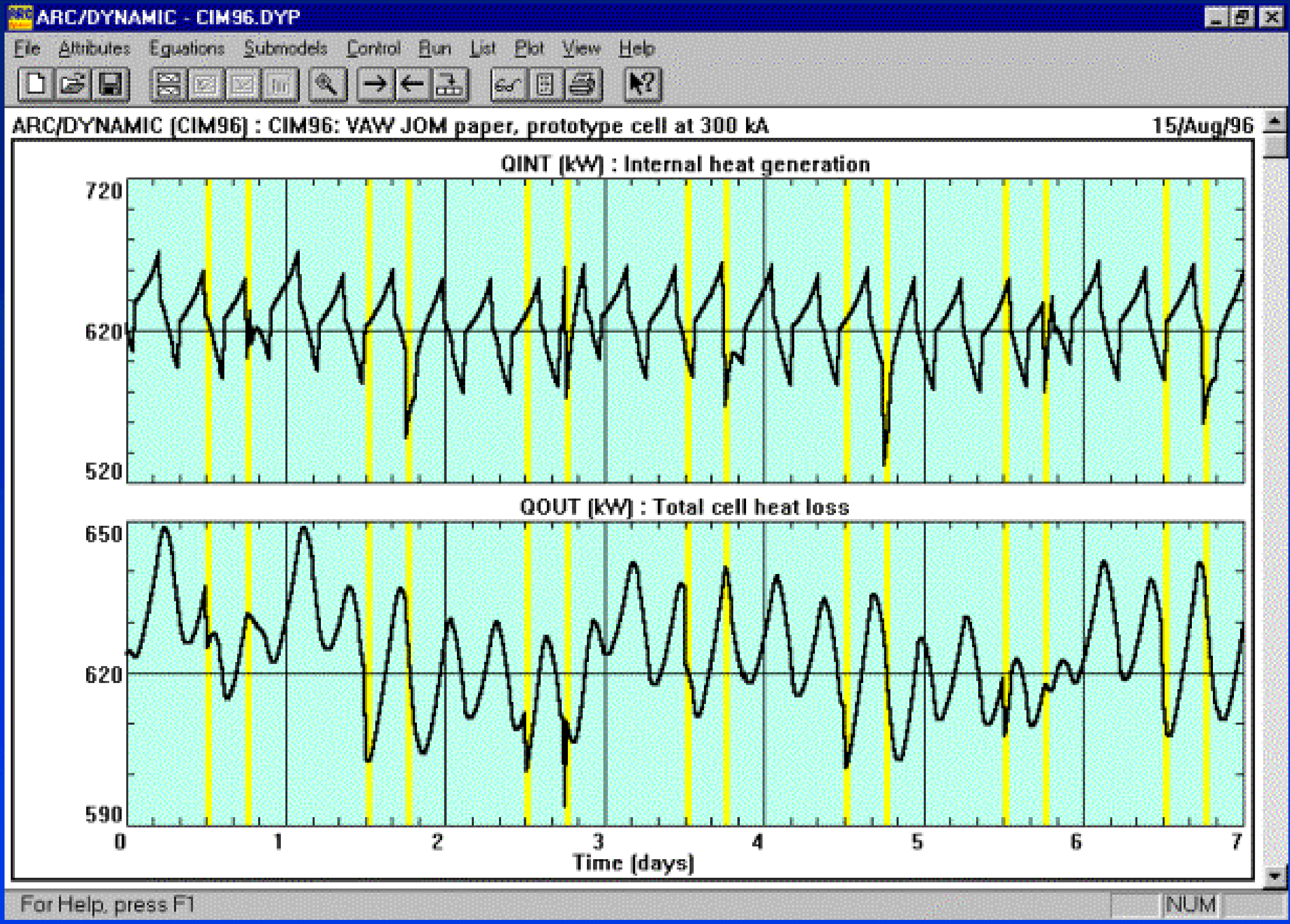


Dynamic Freeze Thickness Distribution



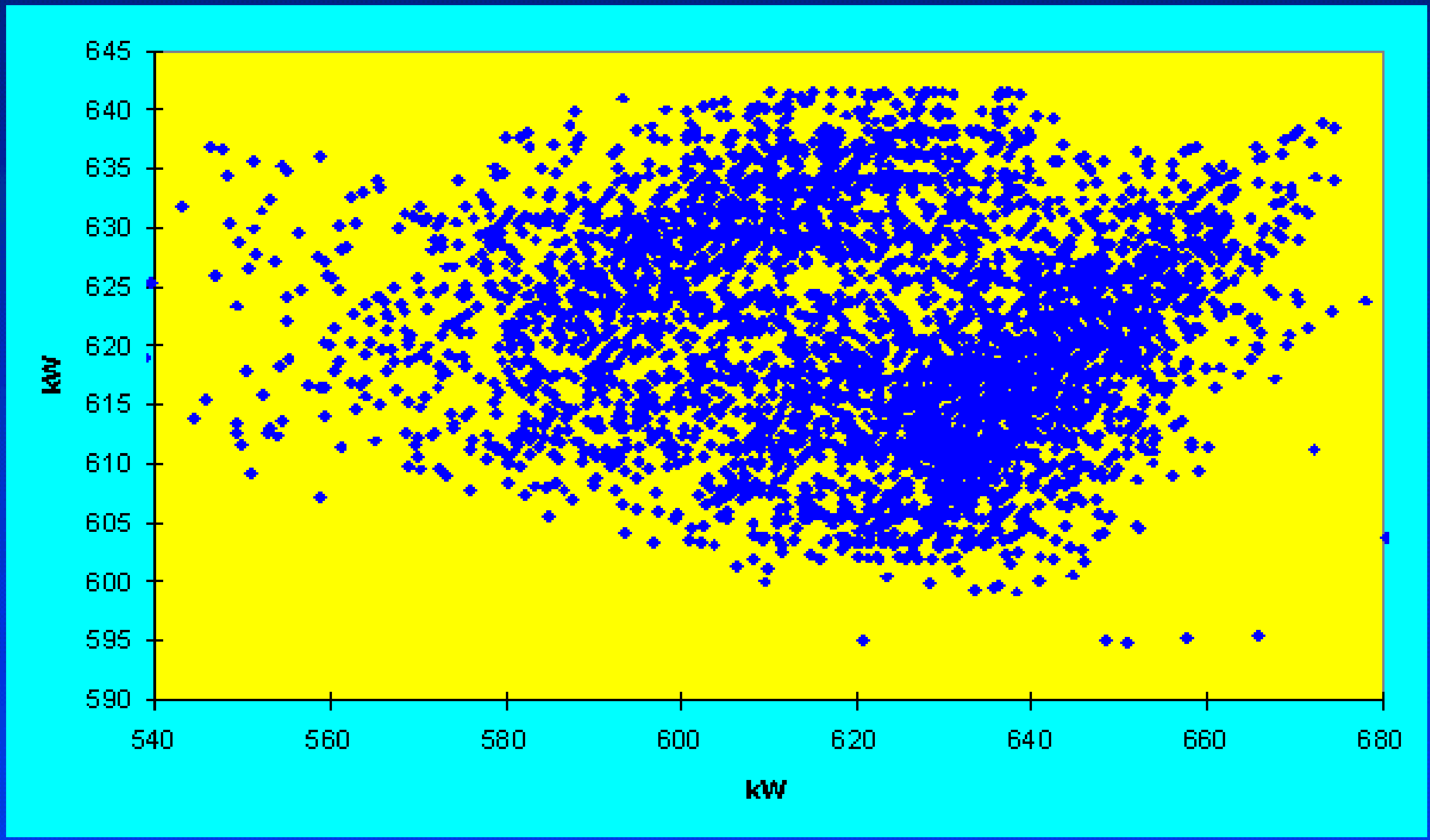
GENISIM

Analysis of Dynamic Response

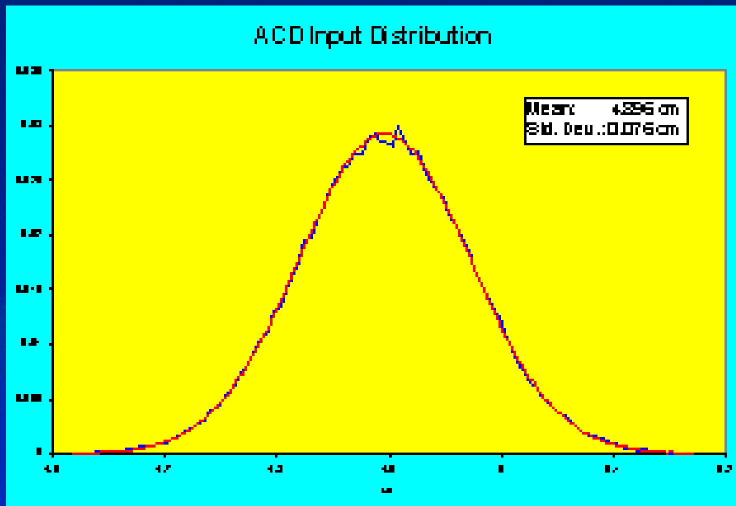


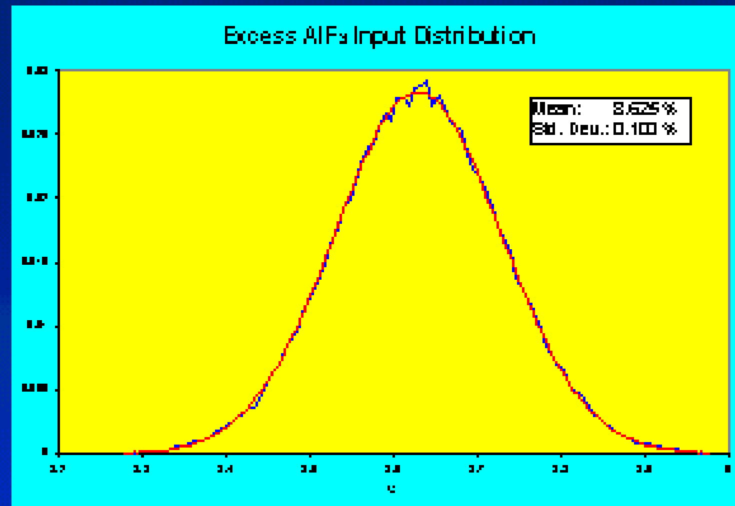
GENISIM

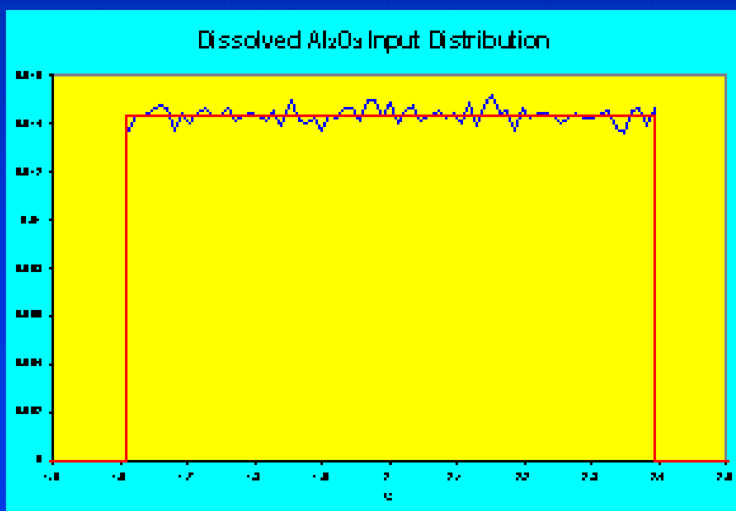
Dynamic Solution
Heat Loss vs Internal Heat

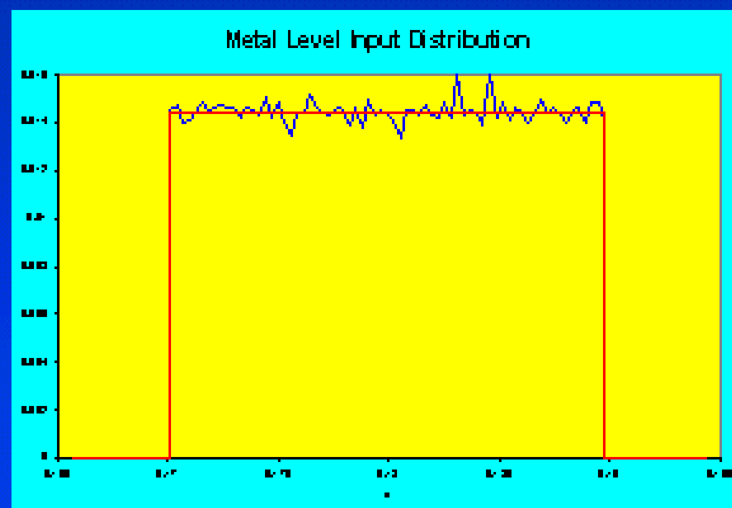


Example of Monte Carlo Input Distributions



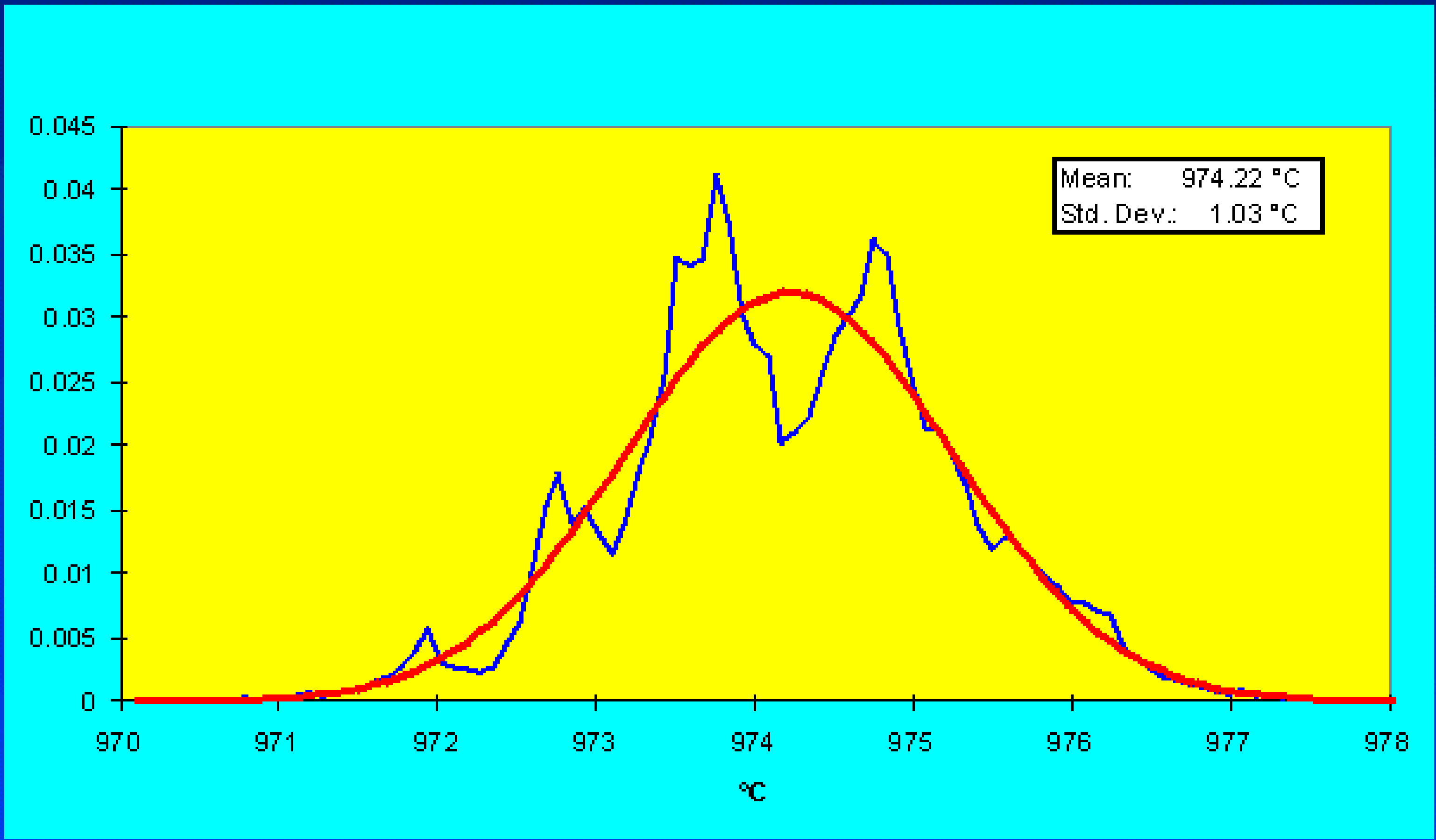






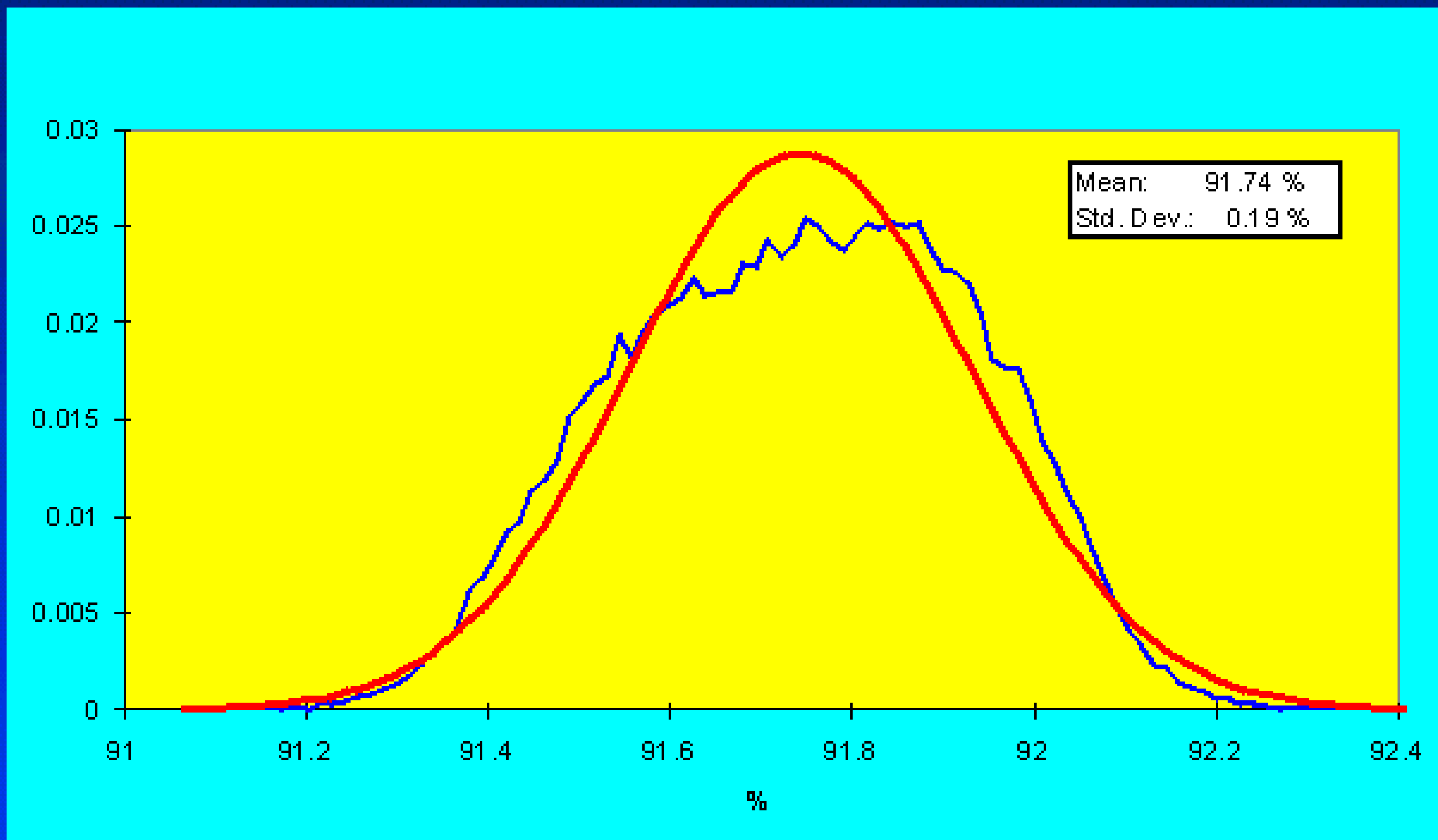
GENISIM

Monte Carlo Output
Temperature Distribution

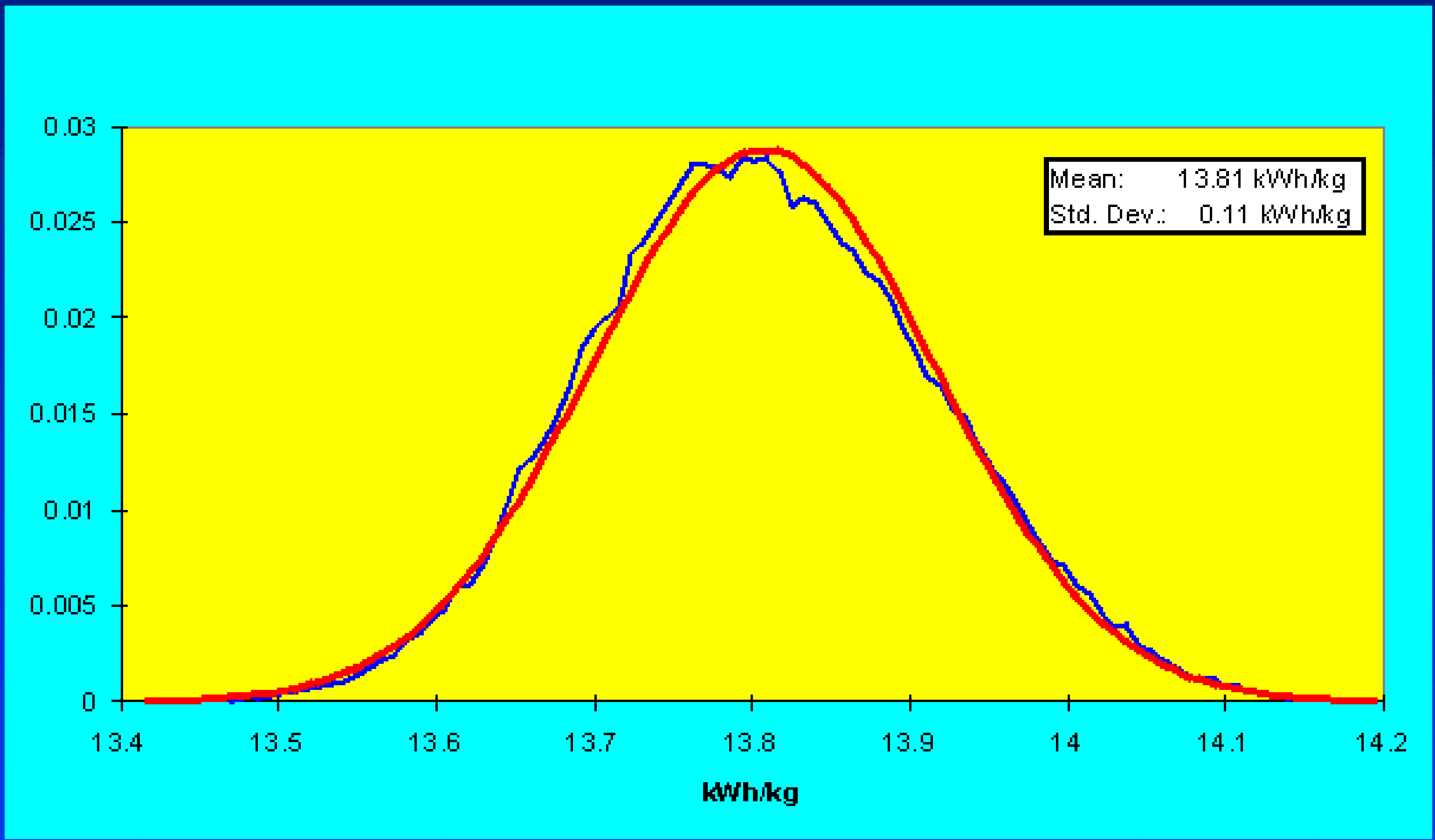


GENISIM

Monte Carlo Output
Current Efficiency Distribution

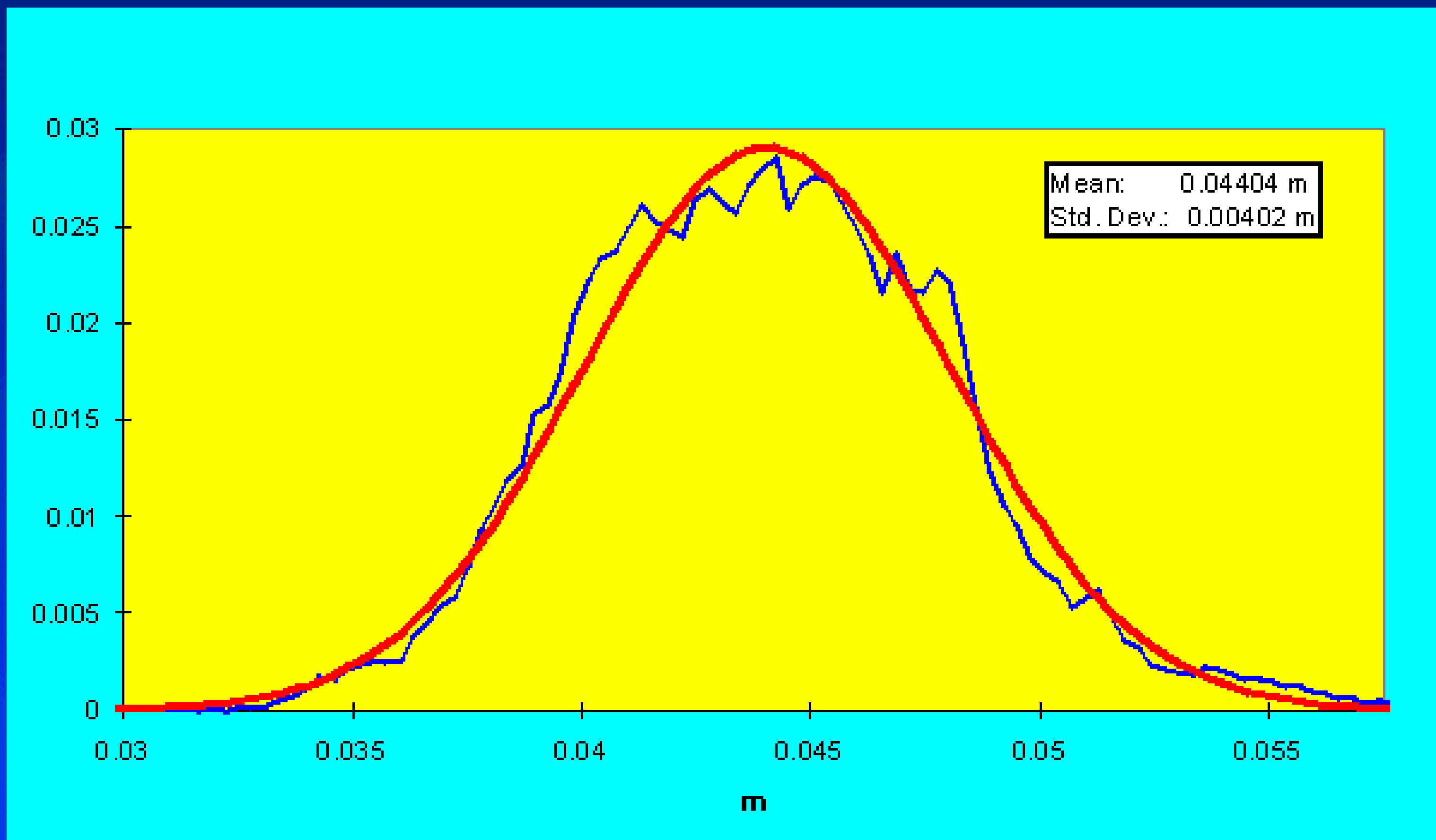


Monte Carlo Output
Energy Consumption Distribution



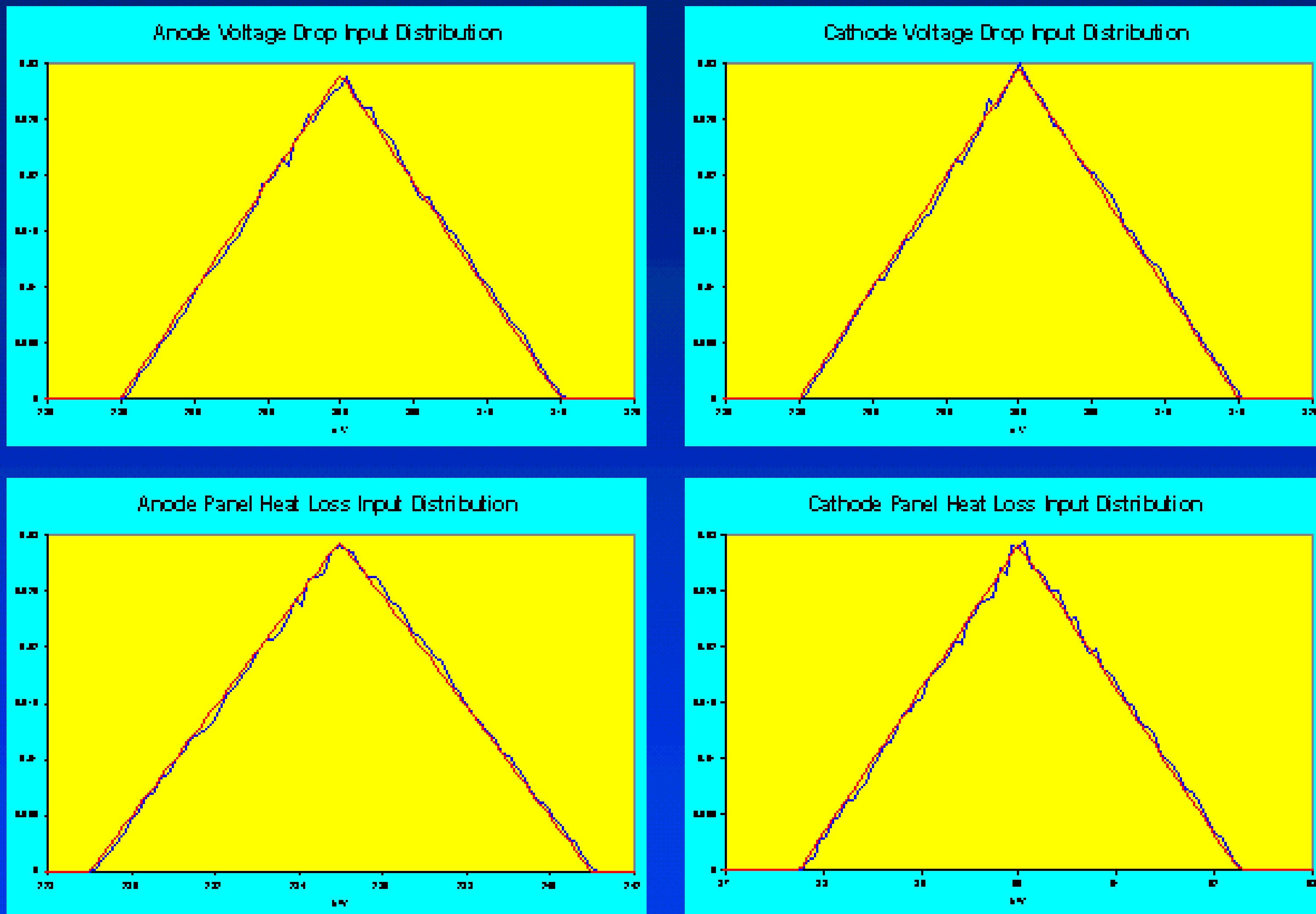
GENISIM

Monte Carlo Output
Freeze Thickness Distribution

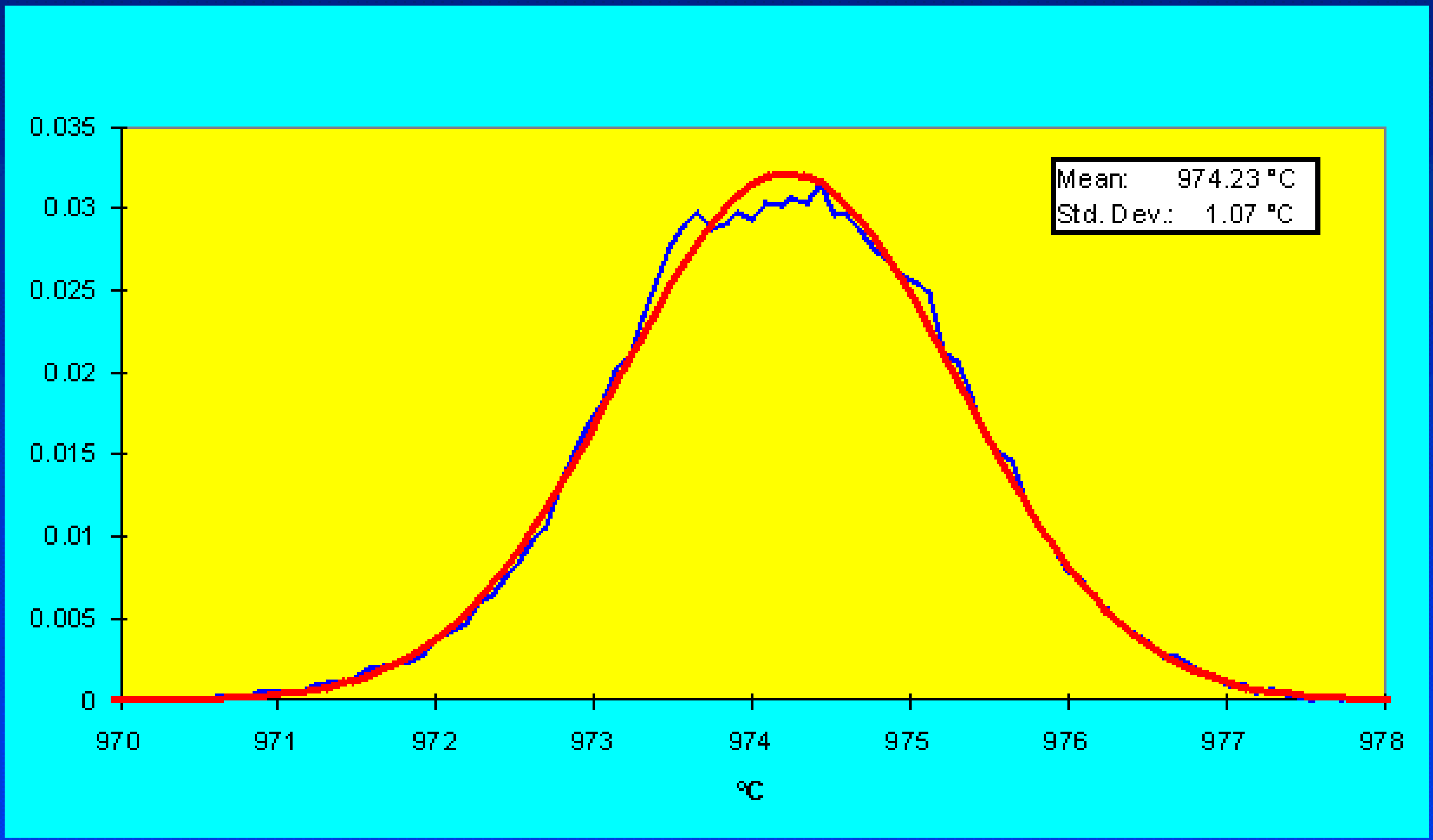


GENISIM

Sensitivity Study Input Distributions

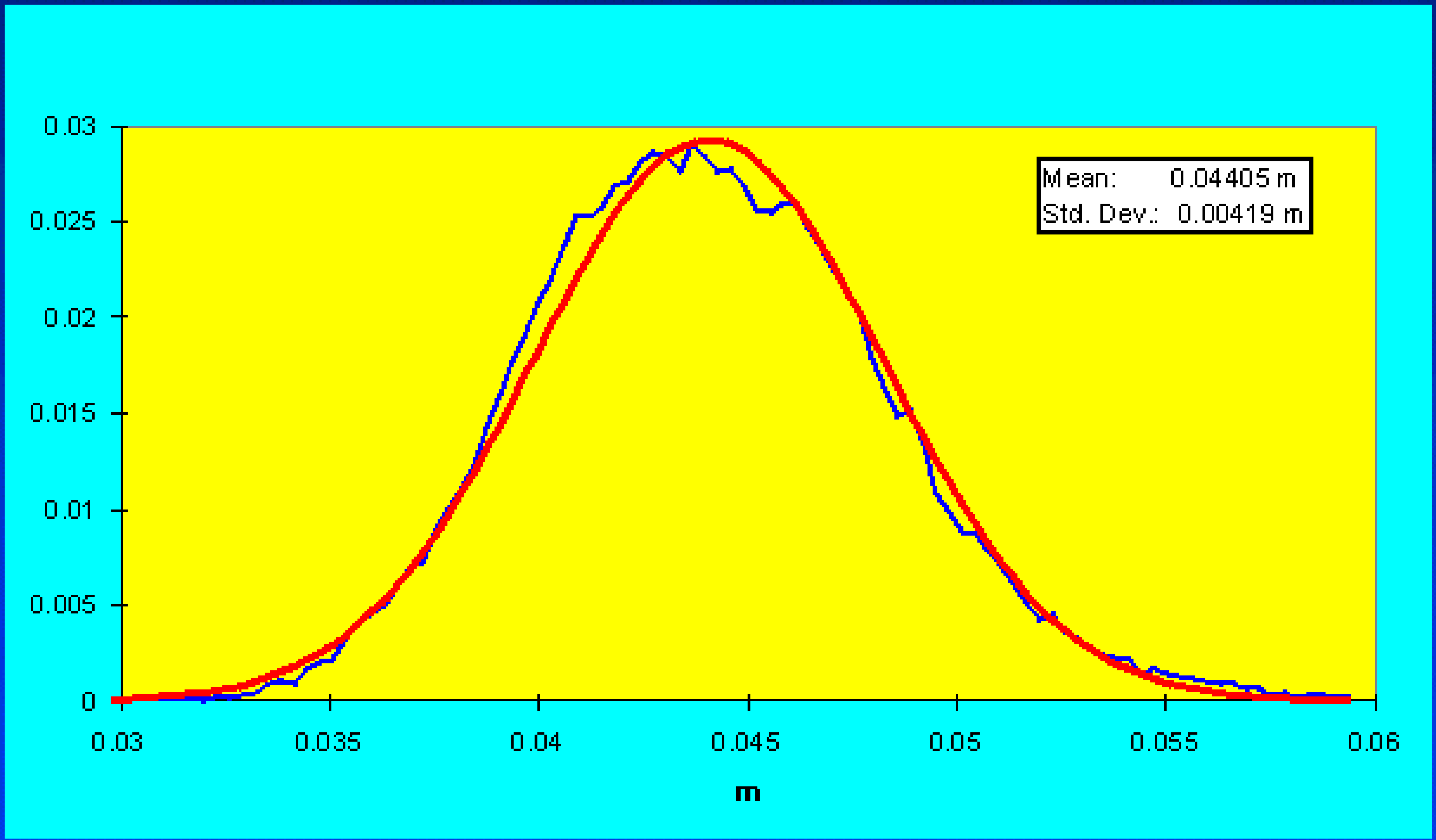


Sensitivity Study Output
Temperature Distribution



GENISIM

Sensitivity Study Output
Freeze Thickness Distribution



GENISIM

Summary of Outputs
Distribution Results

	Dynamic		Monte Carlo		Sensitivity Study	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Temperature	974.39	1.38	974.22	1.03	974.23	1.07
CE	91.79	0.24	91.74	0.19	91.74	0.19
kwh/kg	13.85	0.15	13.81	0.11	13.81	0.11
Frz. Thick.	4.304	0.269	4.404	0.402	4.405	0.419

Conclusions

- An enhanced program has been developed to model the steady state behavior of reduction cells.
- The program can be used to perform Monte Carlo analysis by assigning probability functions to input parameters.
- By using input parameters distributions that mimic those obtained from dynamic analysis, it is possible to use a Monte Carlo analysis to reproduce output dynamic analysis distributions.
- By adding input distributions for design variables, it is possible to perform design sensitivity analysis or risk assessment analysis.
- The effect of a ± 5% accuracy on design parameters was demonstrated to have a minor impact on the obtained output distributions.

GENISIM